

REMARKS

This Preliminary Amendment cancels, without prejudice, claims 1-13 in the underlying PCT Application No. PCT/DE2004/001352 and adds new claims 14-28. The new claims, inter alia, conform the claims to United States Patent and Trademark Office rules and do not add any new matter to the application.

In accordance with 37 C.F.R. § 1.125(b), the Substitute Specification (including the Abstract) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to United States Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. §§ 1.121(b)(3)(ii) and 1.125(c), a Marked-Up Version of the Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. Approval and entry of the Substitute Specification (including Abstract) are respectfully requested.

The underlying PCT Application No. PCT/DE2004/001352 includes an International Search Report, dated November 19, 2004, a copy of which is included. The Search Report includes a list of documents that were considered by the Examiner in the underlying PCT application.

It is respectfully submitted that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

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Respectfully Submitted,

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RECTIFIER SYSTEM HAVING DIFFERENT RECTIFIER ELEMENTS

~~Background Information~~ BACKGROUND INFORMATION

Rectifiers for motor vehicle three-phase generators are normally equipped with 6 silicon diodes which are connected to form a bridge.

It is a characteristic of all of these rectifier configurations

5 that ~~as a rule they~~ generally are either equipped only with high-blocking diodes, i.e., diodes without a voltage limiting function, or Zener diodes, i.e., diodes having a voltage limiting function. In doing so, only semiconductor diodes of the same type are used. An exception is rectifiers in which an additional pair
10 of diodes is connected to the star point of the generator stator winding. For reasons of cost, the star point diodes in this case are sometimes designed as high-blocking diodes while, however, the phase diodes are designed as Zener diodes.

15 Rectifiers having 7, 8, 12, 14 or more diodes are also in use. In doing so, the number of diodes is then doubled from 6 to 12, when high temperature or current demands in particular must be met. The diodes are then connected in such a way that two diodes are connected in parallel.

20 The level of the rectified signal, i.e., the generator current or the generator voltage, shows a characteristic variation which is a function of different influence factors. This variation is known as generator ripple. The reverse recovery time t_{rr} of the diodes
25 makes a significant contribution to generator ripple. Reverse recovery time t_{rr} is a form of switching time.

When conventional generators are operated at high speeds and large currents, the voltage ripple or current ripple increases strongly
30 because the current sloped IF/dt to be switched increases.

~~Advantages of the Invention~~

SUMMARY

5 ~~The~~An example rectifier system according to the present invention
hasmay have the advantage that the voltage ripple or current ripple
stays low even at high speeds and large currents, making it possible
to use the rectifiers ~~according to the present invention using~~
diodes even in generators having high output. ~~This advantage is~~
10 ~~achieved through the combination of features specified in Claim~~
~~1, according to which~~According to an example embodiment of the
present invention, a rectifier system, in particular a rectifier
bridge, ~~including~~includes a plurality of rectifier elements, ~~and~~
is designed in such a way that specifiable rectifier elements
15 differ from the other rectifier elements in at least one property.
The rectifier elements ~~are~~may advantageously be diodes.

~~Additional advantageous embodiments are obtained through the~~
~~measures specified in the dependent claims. It is~~It may be
20 advantageous in particular that it is also possible to reduce
significantly the voltage ripple or current ripple in rectifier
systems which are intended to remain functional at very high
currents by doubling the number of diodes used and connecting every
two diodes in parallel, the diodes connected in parallel having
25 at least one different property.

The properties with regard to which the rectifier elements or
diodes used differ from one another ~~are~~may advantageously be the
switching time or the reverse recovery switching time (t_{rr}) and/or
30 the current density and/or the chip area and/or the chip thickness
and/or the breakdown voltage (U_Z) and/or the internal resistance
(R_I) and/or the path resistance and/or another property which is
suited for reducing ripple. The combination of the diodes having
the advantageous properties is selectable based on requirements.
35 Other combinations of diodes which differ in at least one property
are conceivable both for rectifiers having 6 but also 12 diodes.

Drawing

BRIEF DESCRIPTION OF THE DRAWINGS

One exemplary embodiment of the present invention is depicted in the drawing figures and is explained ~~in the following description.~~
5 ~~In particular, below.~~

Figure 1 shows an embodiment of a rectifier bridge according to the present invention having different rectifier elements.

10 Figure 2 schematically depicts the variation of the diode current over time during a switching operation.

Description

15 DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

One exemplary embodiment of a rectifier system is shown in Figure 1.

This rectifier system includes a rectifier bridge having six
20 positive diodes PD and six negative diodes MD, thus a total of 12 diodes, diodes D11 through D16 (D1) being different from diodes D21 through D26 (D2) in at least one property. The diodes according to the exemplary embodiment are Zener diodes; suitable rectifier elements may generally be used. Every two diodes having different
25 properties are connected in parallel, for example, diode D11 and diode D21.

The rectifier bridge may be connected to a generator G via terminals A1, A2, A3, it being ~~basically~~generally possible to feed the signal
30 to be rectified, i.e., a voltage or a current, via these terminals. The rectified signal appears at terminals A4 and A5. Normally, terminal A5 is connected to ground.

The parallel connection of specifiabile diodes makes the rectifier
35 system shown in Figure 1 suitable for use with generators having very high currents and it is still able to process the high output given off by the generator even at high speeds, i.e., to rectify the generator voltage or the generator current.

Diodes D1 and D2, as well as D11 through D16 and D21 through D26 differ from one another with regard to at least one property, if necessary also in a combination of properties, this property or properties being the switching time or the reverse recovery switching time (t_{rr}) and/or the current density and/or the chip surface and/or the chip thickness and/or the breakdown voltage (U_Z) and/or internal resistance (R_I) and/or the path resistance or another property which is suited for reducing ripple.

In addition to the example embodiment shown in Figure 1, other combinations of diodes or rectifier elements are also possible. For example, the "lower," i.e., the minus, diodes may be made up of only one diode type. All of diodes MD would then be of the same type while positive diodes PD differ with respect to D1 and D2. The reverse system is also possible.

Another example embodiment uses different diode types or diodes having different properties in only one or two lines. Additional embodiments may include nine diodes, for example, six positive diodes connected in parallel in the manner described and three negative diodes MD.

Figure 2 shows the basic curve of diode current I_F during a switching-off operation over time t . In this connection, it should be noted that when a high diode current having a gradient dI_F/dt is switched off at the point in time of the transition from flow to blocking polarity for a specific period of time, reverse recovery time t_{rr} causes a current to flow in reverse direction I_r because minority charge carriers in the diode must be cleared out or reduced first, the following being the case: $Q_{\text{charge carrier}} = f \cdot (I_G, T_{\text{CHIP}})$. Reverse recovery time t_{rr} may be divided into a time segment t_1 and a time segment t_2 .

Frequently, current chopping in second time segment t_2 is very abrupt, i.e., current change dI_r/dt at maximum reverse current $I_{r\text{max}}$ is very great. $I_{r\text{max}}$ represents the reverse current recovery

point. The above conditions have the result that only a low soft factor is obtained. Soft factor denotes the relationship $s = t_2/t_1$.

It is possible to estimate the resulting voltage ripple at ΔU_g
5 = $LBN \cdot dI_r/dt_{max}$ where:

t_{max} : time of maximum current change dI_r/dt is generally identical to the point in time of the maximum reverse current.

10 LBN: vehicle electrical system inductance

If diodes having different reverse recovery times are now connected in parallel, it is possible to set the current chopping to be softer, i.e., having a lower I_r/dt_{max} . This is expressed in lower ripple
15 of the rectified voltage and accordingly of the rectified current. According to an example embodiment of the present invention, it is thus possible to reduce ripple by using specific diodes or rectifier elements.

20 According to the present invention, a diode D1 having a high soft factor s_1 and a diode D2 having a low soft factor s_2 are connected in parallel. If diode D1 is operated at a 20%-40% lower current density than diode D2, for example, the diodes reach the reverse current recovery point at different times. This results in soft
25 switching overall, i.e., in a higher soft factor of the entire system.

When used in a rectifier system having a plurality of rectifier elements, diodes in particular, it is possible to design the
30 rectifier system in such a way that parallel circuits of diodes having different properties are used at specifiable places, it being necessary to select the diodes with consideration of the effects to be obtained. A preferred application for the rectifier bridge is in a high-output generator in a motor vehicle.

35 In summary, the present invention may be used to obtain a reduction of generator ripple by connecting in parallel diodes having different reverse recovery properties and/or different current

densities. In order to obtain the different reverse recovery characteristics, it is possible to use diodes having different breakdown voltages and, for example, semiconductor diodes in the Zener voltage range of 18 volts through 50 volts combined with
5 diodes in the Zener voltage range of 100 volts through 800 volts. Different current densities may be implemented through different chip areas and/or different chip thicknesses and/or different path resistances of the semiconductors.

~~Abstract~~ ABSTRACT

A rectifier system, in particular a rectifier bridge for a three-phase generator, includes a plurality of rectifier elements, specifiable rectifier elements being different from the other rectifier elements in at least one property. The rectifier elements are, for example, diodes which differ from one another with regard to the following properties: switching time or the reverse recovery switching time ~~(t_{rr})~~ and/or current density and/or chip area and/or chip thickness and/or the breakdown voltage ~~(U_Z)~~ and/or internal resistance ~~(R_i)~~ and/or path resistance and/or with regard to another property which is suited for reducing ripple.

~~(Figure 1)~~